CHAPTER 4

MIDTERM BENEFITS ANALYSIS OF EERE'S PROGRAMS

Introduction

The results of the **Step 2** program and market analyses are incorporated into NEMS-GPRA06 in the Program and Portfolio Cases to estimate the midterm (to 2025) benefits for each program and for EERE's overall portfolio. In some cases, NEMS-GPRA06 can directly utilize program performance goals (outputs). In other cases, analysts need to make adjustments to the program analyses when incorporating them in NEMS-GPRA06. This chapter describes the NEMS-GPRA06 analyses for each program. The appendices provide additional information on the inputs provided by each program.

Table 4.1 shows a breakdown by program of the two types of analytical tool employed in its benefits analyses—specialized "off-line" tools and NEMS-GPRA06. A description of EIA's NEMS model is provided in **Box 4.1** at the end of this chapter. Descriptions of the off-line tools are provided in the related program appendix.

Table 4.1. Program Benefits Modeling by Primary Type of Model Used and Activity Area

Program	Activity Area	Off-Line Tool	NEMS-GPRA06
Biomass	Bio-based Products	✓	
	Cellulosic Ethanol	✓	✓
Building Technologies	Technology R&D	✓	✓
	Regulatory Actions	✓	✓
	Market Enhancement	✓	
DE	DE		✓
FEMP	FEMP	✓	
Geothermal	Geothermal		✓
Hydrogen, Fuel Cells, and Infrastructure Technologies	Fuel Cells		✓
	Production and Delivery	✓	
Industrial Technologies	R&D	✓	
	Deployment	✓	
Solar Energy Technologies	Solar Water Heaters		✓
	Photovoltaics	✓	✓
	Concentrated Solar Power		✓
Vehicle Technologies	Light Vehicle Hybrid and Diesel		✓
	Heavy Vehicles	✓	✓
Weatherization and Intergovernmental	Weatherization	✓	
	Domestic Intergovernmental	✓	
Wind and Hydropower Technologies	Wind		✓

Required off-line analysis can range from simple verification of program goals to an initial calculation of energy savings, depending on the treatment of the target market in NEMS-GPRA06 and the nature of the program. Analysts use specialized off-line tools to develop the inputs to NEMS-GPRA06 for each program case. The activity areas listed are groupings of activities within each program that share either technology or market features. They do not represent actual program-management categories.

Biomass Program

The goal of the Biomass Program is the development of biomass refineries (biorefineries), which produce a range of products including ethanol and/or other fuels, chemicals, materials, and/or power. The biorefinery concept allows the cost of production to be reduced through synergies associated with feedstock handling and processing, and the allocation of capital and fixed O&M costs across multiple products. The current analysis is based on two types of biorefineries. The first type produces chemicals and materials, but not fuels, and the second type produces ethanol fuel as the major output. Future analyses could include additional fuels that the program may identify in the longer term.

Bio-based products from nonfuel biorefineries: The use of biomass would displace the use of petroleum and natural gas as chemical feedstocks. Because of the multitude of products and the complexity of the chemicals industry, NEMS-GPRA06 does not have sufficient detail within its representation of this industry to explicitly model bio-based products. Given the lack of a bio-based products sector in the model, analysts assessed energy savings off-line. The energy savings by fuel type (the largest share was petroleum feedstocks) were implemented in the integrated model, by subtracting the estimates from industrial energy consumption otherwise projected by NEMS-GPRA06. Analysts then used the model to compute the other benefits of primary energy savings, carbon emission reductions, and energy-expenditure savings.

Cellulosic ethanol from biorefineries dedicated to the production of ethanol, lignin-derived electricity, and chemical coproducts: EERE is sponsoring research aimed at reducing the cost of producing ethanol from cellulosic biomass.[1] The second type of biorefineries assumed in this analysis is one that focuses on producing ethanol, lignin-derived electricity, and a small quantity of chemical coproducts. Estimates of future cellulosic ethanol production costs in the *AEO2004* and the Baseline Case are comparable. The biomass-to-ethanol conversion efficiencies for both the Baseline and Program Cases reflect more updated information than the *AEO2004* assumptions. In the *AEO2004*, EIA assumed that the growth in projected production was constrained by a number of factors in addition to ethanol production costs. In the Baseline Case, EERE was more conservative in terms of constraining the growth in cellulosic ethanol production in the absence of EERE programs, with production at roughly one-fifth of the *AEO2004* values. EERE's biofuels analytic model, ELSAS Bioref, was used to estimate the growth of ethanol made from agricultural residues (such as corn stover) and other cellulosic biomass.[2] The two cellulosic ethanol estimates were combined and input into NEMS-GPRA06. Petroleum and fossil energy savings occur when the cellulosic ethanol displaces gasoline or corn ethanol in the ethanol blend market for gasoline. In the FY 2006 EERE mid-term benefits estimates, a large portion of the cellulosic ethanol displaces corn ethanol, which leads to fossil

[1] Cellulose and hemi-cellulose that can be converted to ethanol (and other chemicals, materials, and biofuels) are found in biomass such as agricultural residues (corn stover, wheat, and rice straw), mill residues, organic constituents of municipal solid wastes, wood wastes from forests, future grass, and tree crops dedicated to bio-energy production.

[2] For more information on the off-line analysis, see Appendix B.

energy and carbon emission savings based on recent EERE life-cycle analysis. Fossil energy requirements and carbon emissions to produce ethanol fuels were obtained from EERE's Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model. The Biomass Program benefits shown in **Table 4.2** are the reductions in energy use and carbon emissions in the Program Case compared with the Baseline Case.

Table 4.2. FY06 Benefits Estimates for Biomass Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	ns	0.02	0.06	0.12
Cellulosic Ethanol Production (billion gallons/yr)	0.00	0.12	0.26	1.57
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	ns	ns	ns
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.0	0.4	1.6	2.6
Security				
Oil Savings (million barrels per day)	ns	0.00	0.01	0.01
Natural Gas Savings (quadrillion Btu/yr)	ns	ns	ns	0.02
Avoided Additions to Central Conventional Power (cumulative gigawatts)	ns	ns	ns	ns

Building Technologies Program

The activities of the Building Technologies Program can be classified into three general types: technology R&D, regulatory actions, and (to a far lesser extent) market enhancement.[3] The modeling approach and applicable end uses for the activities that comprise the Building Technologies Program are displayed in **Table 4.3**. Analysts model the technology R&D activities by modifying costs and efficiencies of the equipment and shell technology slates. Market-enhancement activities and some regulatory activities (such as buildings codes) are modeled using penetration rates and energy-savings estimates. A few R&D activities such as residential incandescent light fixtures were not modeled, because they represented a small segment of the market and are not explicitly represented within NEMS-GPRA06.

Technology R&D: The technology R&D activities seek to develop new or improved technologies that are more energy efficient and more cost-effective than the alternatives currently available. The forecast benefits for these are measured by modifying the technology slates from those that are available in the Baseline Case to reflect the program goals. Building technologies in NEMS-GPRA06 are represented by end use. For most end uses, there are conversion technologies (*e.g.*, furnaces and water heaters) that use different fuels and that have several different levels of energy efficiency. The Baseline Case incorporates EIA's estimation of future technology improvement that is then modified in the Program Case.

[3] With the reorganization of EERE, the overwhelming majority of the market-enhancement activities are part of the Weatherization and Intergovernmental Program.

Residential shell technologies (such as windows or insulation) for new buildings are represented by several packages of technologies with different levels of improvements. Each package is characterized by a capital cost and heating and cooling load reductions. The commercial-sector shell measures are represented by window and insulation technologies that can be selected individually. EIA developed the residential methodology for the *AEO2001*, while OnLocation developed the commercial methodology for EERE.

Table 4.3. Modeling Approach for Building Technologies Program Activities

	Sector		End-Use					Modeling Approach		
Building Technology Project List	Resd	Comm	Heat	Cool	Water Heating	Lighting	Other	Energy Savings and Penetration Rates	Equipment Technology Costs and Efficiencies	Shell Technology Costs and Efficiencies
Residential Buildings Team										
Research and Development (Building America)	✓		✓	✓	✓	✓	✓			✓
Residential Building Energy Codes	✓		✓	✓				✓		
Commercial Buildings Team										
Commercial Research and Development		✓	✓	✓				✓		
Commercial Building Energy Codes		✓	✓	✓		✓		✓		
Standards										
Commercial Unitary AC/HP (EPAct)		✓	✓	✓					✓	
Distribution Transformers										
Analysis Tools and Design Strategies		✓	✓	✓				✓		
Appliances and Engineering Technologies										
Roof top AC		✓		✓					✓	
Can Lights	✓					✓				
R-Lamp	✓					✓				
Window Technologies										
Electrochromic Windows		✓	✓	✓		✓				✓
Superwindows	✓		✓	✓				✓		✓
Low-E Market Accpetance	✓	✓	✓	✓				✓		
Lighting Research and Development										
Lighting Controls		✓				✓		✓		
Solid State Lighting	✓	✓				✓			✓	
Refrigeration R&D										
Unitary DX System	✓	✓	✓	✓					✓	
Remote Fault Detection & Diagnostics	✓	✓	✓	✓					✓	
Commercial Refrigeration		✓							✓	
Ventilation Load Reduction		✓	✓	✓					✓	

The residential and commercial sectors are each represented by several building types within nine Census divisions. NEMS-GPRA06 computes end-use technology choice for each of these building types and geographic regions, based on the relative economics and estimations of consumer behavior for the technologies. The latter is important to replicate current technology market shares. In a few cases where NEMS-GPRA06 has insufficient detail for explicit technology representation, analysts computed market penetration using off-line tools, and the results were implemented with NEMS-GPRA06 through efficiency factors.

Regulatory activities: Regulatory activities include setting new appliance standards, based on the legislatively mandated schedule and encouraging state adoption of more stringent building codes.[4] Representing appliance standards is straightforward. In the year that the program expects the new standard to be implemented, all technologies that are less efficient than the standard are

[4] The outreach/deployment aspects of the codes process occur with funding provided by the Weatherization and Intergovernmental Program.

removed from the market and unavailable for consumer choice. The resulting energy savings depend on the difference in the level of efficiency of the standard compared to the technology that had been selected in the Baseline Case.

Market enhancement: Building-code development is primarily a regulatory activity, although it also involves outreach to encourage the various states to adopt new and stricter standards. Analysts make a spreadsheet computation of average savings using off-line estimates for the fraction of buildings within areas that adopt more stringent codes, as well as the heating, cooling, and lighting load reductions associated with the new levels of codes. The building shell packages in NEMS-GPRA06 are modified to produce the appropriate savings.

The Building Technologies Program results in energy savings primarily in four end-use categories: space heating, space cooling, water heating, and lighting. **Table 4.4** demonstrates the level of savings from each category. In 2025, cooling and space-heating end uses have the highest savings in residential buildings, while the lighting energy-use reduction is the largest in commercial buildings.

Table 4.4. Building Technologies Program Energy Savings by End Use

Energy Reduction	Residential				Commercial			
Percentage	2010	2015	2020	2025	2010	2015	2020	2025
Space Heating	0%	2%	3%	5%	0%	1%	2%	2%
Space Cooling	0%	2%	4%	8%	1%	2%	3%	2%
Water Heating	0%	0%	0%	0%	0%	0%	0%	0%
Lighting	0%	0%	0%	1%	0%	1%	2%	10%
Other	0%	0%	0%	0%	0%	0%	0%	0%

Analysts estimate the Building Technologies Program benefits (**Table 4.5**) within the integrated NEMS-GPRA06, so that the electricity-related primary energy savings are directly computed. In addition, the estimates include any feedbacks in the buildings or other sectors resulting from changes in energy prices that result from the reduced energy consumption.

Table 4.5. FY06 Benefits Estimates for Building Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.09	0.31	0.62	1.24
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	1.8	5.0	7.5	11.5
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	1.6	6.3	13.6	28.4
Security				
Oil Savings (million barrels per day)	0.01	0.02	0.03	0.02
Natural Gas Savings (quadrillion Btu/yr)	0.05	0.10	0.14	0.28
Avoided Additions to Central Conventional Power (gigawatts)	ns	8	19	33
Total Electricity Capacity Avoided (cumulative gigawatts)	ns	9	19	36

Distributed Energy Program

The Distributed Energy (DE) Program encompasses many technologies and markets. The benefits were estimated by focusing on several segments of the distributed energy market: gas-fired combined heat and power (CHP) systems in commercial building and industrial applications, and non-CHP grid support applications. Distributed energy applications that are motivated by the need for electric reliability primarily will be systems that produce only electricity and are used in backup mode. In the program analysis, these are represented as grid-support DE for their similar technology characteristics, although the model treats them as though they are purchased by electric-power producers rather than electricity-consuming businesses. The value of these systems is difficult to capture in the GPRA benefits metrics. They do not provide significant energy or emissions savings, because they run for only a few hours per year and generally have similar or lower efficiencies than larger central-station peaking facilities. They do have the potential to contribute significantly to new electric power-generating capacity. The benefit estimates do not account for increased reliability and local Clean Air Act impacts on demand.

Combined heat and power systems produce both useful thermal heat and electricity. Their economics depend on the amount of thermal heat needed at the site, the electricity usage at the site, the price of the input fuel, and the value of the electricity. If the end-use customer is making the investment, the electricity value will depend on the customer-avoided purchases at the electricity retail price, and possibly the amount of excess electricity sold off-site at prevailing wholesale electricity prices. Using the average electricity price is a simplification that may overlook the requirement to continue paying some type of flat distribution charge, even though less electricity is purchased from the utility. If a vertically integrated electric utility is making the investment, the value is from avoided generation, and transmission and distribution (T&D) costs. The distributed systems would be placed strategically in the grid to avoid T&D expansion costs.

The DE Program facilitates the development of the DE market by improving the technology characteristics (lowering costs, improving efficiency, and reducing environmental emissions) and by removing barriers to adoption and consumer acceptance. Thus, the benefits are estimated based on the impact of improved technology and greater market penetration.

Baseline adjustments: The *AEO2004* Reference Case includes significant DE technological advancement. The Baseline Case includes a modified set of technology characteristics that represented the absence of continued EERE programs. These modifications were made in all three areas in NEMS where distributed technologies are represented: commercial building combined heat and power (CHP), industrial CHP, and utility grid support. For most of the commercial and industrial CHP technologies, the baseline technology characteristics were assumed to be a 10-year lag of the program goals, therefore assuming the baseline technologies will catch up with the policy case in 10 years. The technology assumptions for commercial gas-fired chillers also were modified, and these chillers were assumed to be applicable to all building types; unlike in the *AEO2004,* where they can be used only in the larger building sizes.

The adoption rates of distributed technologies in commercial buildings were modified to reflect market data gathered by EERE on consumer adoption of energy efficiency projects as a function of payback time (**Figure 4.1**).[5] The NEMS-GPRA06 framework uses a cash-flow model to evaluate the DE technologies—CHP and photovoltaic (PV) systems—within the building sectors. For commercial buildings, debt and interest payments are computed over a loan period of 15 years along with associated taxes and tax benefits and assuming a 25 percent down payment. Annual fixed maintenance costs also are included. For the gas-fired CHP technologies, NEMS-GPRA06 computes fuel costs based on the delivered cost of natural gas and the technology efficiency. The value of the useful waste heat produced is netted against the fuel cost, based on the delivered natural gas price, the thermal efficiency of the CHP system, and the internal thermal load. The value of the electricity produced is then subtracted from these costs to determine the cash flow. The value of electricity is equal to the larger of the electricity produced and the internal electricity demand, multiplied by the delivered electricity price. Any electricity produced in excess of internal needs is assumed to be sold to the grid at the wholesale rate. The number of years until positive cash flow is reached determines the market share in new buildings. The market share for existing buildings is assumed to be a fraction of the share for new.

Under both the EIA and program assumptions, market share in new buildings decreases sharply as the number of years required to achieve positive cash flows increases. This reflects the high rates of return generally expected for energy-related projects by commercial-building owners. These shares apply to the fraction of commercial buildings assumed to be eligible for an installation of distributed CHP. The *AEO2004* eligibility fraction assumption of 30 percent was increased to 50 percent. These adoption rate changes were made in the Baseline Case as well as the Program Case.

Technology improvements: The program provided characteristics for distributed energy systems that reflect the program's research goals. These included commercial CHP systems (gas engines, gas turbines, gas microturbines), commercial gas-fired chillers, industrial CHP (five systems sizes for gas-fired engines and turbines), and grid-support DE (base and peaking).

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[5] ***Market Trends in the U.S. ESCO Industry: Results from the NAESCO Database Project***. Goldman, C., J. Osborn and N. Hopper, LBNL, and T. Singer, NAESCO, May 2002, LBNL-49601.

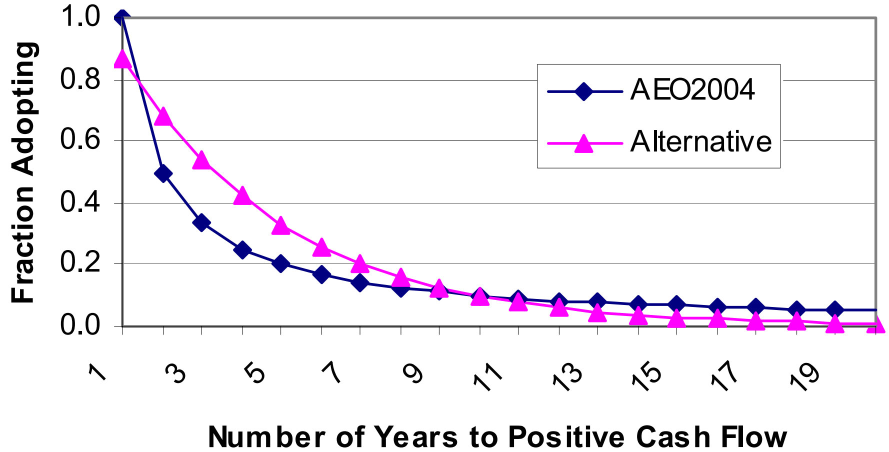

Figure 4.1. Commercial-Sector DG Adoption Rates

Because the thermal output of CHP cannot be used for absorption cooling within NEMS, analysts made an off-line adjustment based on an exogenous customer payback spreadsheet model that determines the impact of absorption cooling on customer payback. In addition, a set of exogenous savings was introduced to account for the potential impacts on end-use consumption of cooling energy savings from increased absorption penetration and increased heating consumption if not all the waste heat was available to meet both the heating and cooling loads.

Market enhancement: The DE Program's impact on consumer-adoption rates was represented by shifting the market adoption rates for industrial CHP systems (**Figure 4.2**). The effect is similar to reducing the acceptance criteria by a year or less. In addition, the penetration rate of the amount of economic potential that is implemented each year was increased from 5 percent to 10 percent for all sizes of gas turbine systems.

The incremental DE capacity that results from this representation of the DE Program activities is shown in **Table 4.6**, along with the projected total quantities. Of the 64 GW of incremental capacity by 2025, roughly 40 percent of the increase is expected to be industrial applications and 59 percent grid-support systems.

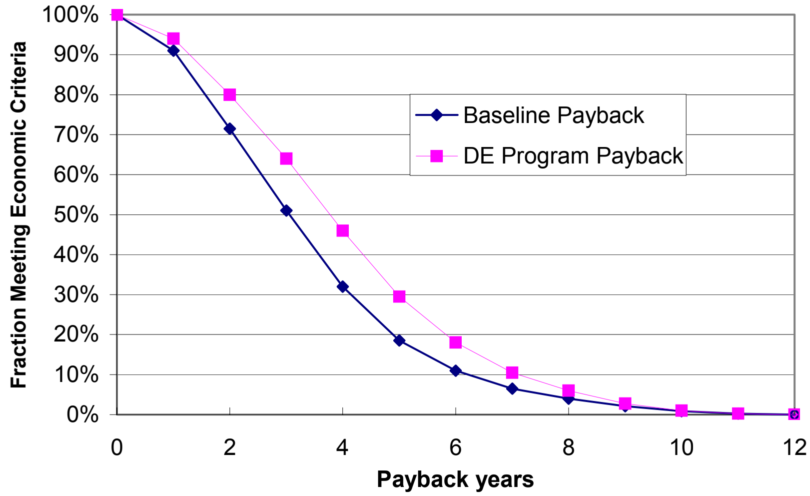

Figure 4.2. Industrial-Sector Combined Heat and Power Adoption Rates

In the Baseline Case, by 2025, the industrial sector is projected to satisfy roughly 20 percent of its total electricity demand with distributed generation. With the DER Program, the share increases to 31 percent.

Table 4.6. Distributed Energy Capacity (GW)

	2010	2015	2020	2025
AEO Base				
Buildings	1.6	1.9	2.4	3.5
Industry*	31.5	35.4	39.6	43.7
Electric Industry	0.5	2.4	7.6	12.4
Baseline Case				
Buildings	2.1	2.6	4.0	9.3
Industry*	30.8	34.7	41.1	48.2
Electric Industry	1.5	1.9	5.0	15.7
Benefits Case				
Buildings	2.1	3.3	4.9	9.8
Industry*	35.8	47.5	60.6	74.2
Electric Industry	3.3	22.4	37.6	53.1
Incremental Capacity				
Buildings	0.0	0.6	0.9	0.5
Industry*	5.0	12.8	19.5	26.0
Electric Industry	1.9	20.5	32.6	37.5
Total	6.9	33.9	52.9	63.9

* Excludes nontraditional, large qualifying facility cogenerators.

The DE Program benefits (**Table 4.7**) are projected within the integrated modeling framework, so that the impact of the program will be reflected in the rest of the energy system. As a result of increased investments in DE, electricity purchases from the commercial and industrial sectors are reduced, and additional electricity is sold wholesale to the grid. The central electricity-generation industry responds by reducing production from the most expensive plants operating in each region, and over time by building fewer central-station plants in the face of lower demand. Retirements are relatively unaffected, with only 3 GW of additional capacity retired by 2025 in the Program Case. Almost 60 GW of central-station investments are avoided by the additional DE. In the Baseline Case, about half of new central-station capacity additions from 2006 to 2025 are projected to be natural gas fired, and about three quarters of the avoided central-station investments are natural gas-fired turbines and combined-cycle plants. In total, distributed generation makes up roughly 15 percent of new capacity additions from 2006 to 2025 in the Baseline Case. This share increases to 36 percent in the Program Case.

The energy- and carbon emission-reduction benefits that stem from distributed generation are computed as the decrease in traditional central-station nonrenewable energy consumption and associated carbon emissions, net of the energy and emissions from the DE. The central-station generation reductions are from a mix of existing plants and avoided new plants. Over time, the facilities that are used in the Baseline Case become more efficient as the central station generation technologies continue to improve. As a result, the energy and emission savings from the central grid decline per kilowatt-hour.

Table 4.7. FY06 Benefits Estimates for DE (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.08	0.13	0.28	0.25
Generation (gigawatt-hours/yr)	37	106	161	210
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	1.6	2.9	ns	1.6
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	2.2	5.5	12.3	11.5
Security				
Oil Savings (million barrels per day)	ns	ns	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	-0.01	-0.21	-0.42	-0.42
Avoided Additions to Central Conventional Power (gigawatts)	2	26	50	56
Program-Specific Electric Capacity Additions (cumulative gigawatts)	7	34	53	64

Federal Energy Management Program

The Federal Energy Management Program (FEMP) is an implementation program to increase the energy efficiency of Federal Government buildings, which account for about 5 percent of U.S. commercial-building energy consumption. FEMP activities support the installation of a variety of existing technologies, rather than focusing on the development of specific technologies, as do many other EERE programs. Because it encompasses a broad technological scope—while, at the same time, targeting a specific market segment—FEMP is difficult to model in an integrated framework such as NEMS-GPRA06. However, there is also less uncertainty associated with achieved energy savings because the program tracks changes in Federal energy consumption.

Delivered energy savings (estimated off-line) are used as inputs for the integrated modeling. These projected savings are subtracted from the Baseline Case for commercial-building energy consumption. Analysts use the model to compute the other benefits metrics of primary energy savings, carbon emission reductions, and energy-expenditure savings (**Table 4.8**).

Table 4.8. FY06 Benefits Estimates for FEMP (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.03	0.04	0.05	0.06
Economic				
Energy Expenditure Savings (billion 2002 dollars/yr)	0.2	0.3	0.4	0.5
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.5	0.7	0.9	1.2
Security				
Oil Savings (million barrels per day)	0.00	0.00	0.01	0.01
Natural Gas Savings (quadrillion Btu/yr)	0.02	0.02	0.02	0.02
Avoided Additions to Central Conventional Power (cumulative gigawatts)	ns	ns	ns	ns

Geothermal Technologies Program

The primary goal of the Geothermal Technologies Program is to reduce the cost of geothermal-generation technologies, including both conventional and enhanced geothermal systems (EGS). Measuring the benefits involves projecting the market share for these technologies, based on their economic and environmental characteristics.

The NEMS-GPRA06 electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (*i.e.*, availability), the regional load requirements, and existing capacity resources. Geothermal capacity is treated in a unique manner, due to the specific geographic nature of the resources. The model characterizes 51 individual sites of known hydrothermal geothermal resources, each with a set of capital and operating and maintenance (O&M) costs. For the Program Case, an additional set of EGS sites were added to this slate.

Baseline adjustments: The EIA *AEO2004* Reference case includes a significant improvement in geothermal generation technology over time, similar to the program goals. To reflect what might occur without continued R&D funding, analysts reduced the cost reduction by half for the GPRA Baseline.

Technology improvements: The Geothermal Program was represented by reducing the capital and O&M costs for all hydrothermal geothermal sites, so that the average of the three lowest-cost sites matched the program cost goals. Separate program technology goals were provided for the added EGS sites. In addition, the program was assumed to reduce the risk associated with new geothermal development, and the Baseline Case limit on the size of annual developments per geothermal site was increased from 25 MW or 50 MW (depending on year) to 100 MW per year.

Table 4.9 shows the resulting additional geothermal capacity and generation, by region and for capacity by technology type. The greatest incremental capacity is in California (CAL) and the Northwest (NWP), with less in the Rocky Mountain area (RA). The primary energy, oil, and carbon emissions savings stem from geothermal power displacing fossil-fueled generation sources. Energy-expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers. **Table 4.10** shows the overall Geothermal Technologies Program benefits.

Table 4.9. Geothermal Capacity and Generation

	2010	2015	2020	2025
GPRA Base Capacity (GW)				
NWP	0.7	1.3	1.6	1.8
RA	0.5	0.7	0.7	0.8
CAL	2.7	3.1	3.5	3.9
Total	3.9	5.0	5.7	6.5
Conventional	3.9	5.0	5.7	6.5
EGS	0.0	0.0	0.0	0.0
Program Case Capacity (GW)				
NWP	1.1	2.1	2.7	3.7
RA	0.5	0.8	0.8	1.6
CAL	2.9	4.0	4.7	6.0
Total	4.5	6.9	8.2	11.4
Conventional	4.5	6.6	6.8	6.8
EGS	0.0	0.3	1.4	4.6
Total	4.5	6.9	8.2	11.4
Incremental Capacity (GW)				
NWP	0.4	0.8	1.1	1.9
RA	0.0	0.2	0.2	0.8
CAL	0.2	0.9	1.3	2.2
Total	0.6	1.9	2.5	4.9
Conventional	0.6	1.6	1.1	0.3
EGS	0.0	0.3	1.4	4.6
Total	0.6	1.9	2.5	4.9
Incremental Generation (BkWh)				
NWP	3	6	9	15
RA	0	1	1	6
CAL	1	7	10	17
Total	5	15	20	39

Table 4.10. FY06 Benefits Estimates for Geothermal Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.01	0.09	0.16	0.33
Generation (gigawatt-hours/yr)	5	15	20	39
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	ns	ns	ns
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.0	1.9	3.9	8.4
Security				
Oil Savings (million barrels per day)	ns	0.01	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	0.02	0.02	0.02	ns
Avoided Additions to Central Conventional Power (gigawatts)	ns	1	2	3
Program-Specific Electric Capacity Additions (cumulative gigawatts)	1	2	3	5

Hydrogen, Fuel Cells, and Infrastructure Technologies Program

The Hydrogen, Fuel Cells, and Infrastructure Technologies Program is targeted toward the introduction of fuel cells for both stationary and vehicular applications, as well as the production and delivery of hydrogen at a reasonable price. NEMS-GPRA06 does not have a representation of hydrogen supply options.[6] Therefore, a simple assumption was used that all hydrogen through 2025 would be derived from natural gas. The hydrogen conversion process was assumed to be 75 percent efficient and yield a hydrogen price of $1.50 per gallon of gasoline equivalent (excluding taxes) when the natural gas price is $4 per MMBtu.

The stationary fuel cell research is focused on distributed proton-exchange membrane (PEM) fuel cells. The program goals for their capital costs and efficiencies were taken from the multiyear program plan (MYPP). The MYPP provides goals through 2010, and no further improvements were assumed. This conservative assumption most likely understates the benefits of these fuel cells. Analysts converted program technology goals into installed costs for combined heat and power systems in residential and commercial buildings.

The fuel cell vehicles were modeled along with the Vehicle Technologies Program. The success of fuel cell vehicles is predicated on some of the vehicular improvements being developed under the Vehicle Technologies Program, so the fuel cell vehicles could not be treated in isolation. Analysts modified the gasoline and hydrogen fuel cell vehicle costs and efficiencies to reflect the program goals (see the Vehicle Technologies Program description for more detail about the modeling of vehicle choice). In addition, hydrogen availability for vehicle refueling was assumed to be 10 percent by 2020 and 25 percent by 2025. The benefits associated with fuel cell vehicles were derived by comparing the amount of fuel cell vehicles from the case with "both Hydrogen and Vehicle Technologies" to the "Vehicle Technologies only" case. Analysts computed energy savings, oil savings, and carbon emission reductions, based on the incremental fuel cell vehicles

[6] Hydrogen is represented within the refinery model of NEMS-H2, but for internal use only.

assuming conventional gasoline vehicle displacement (**see Figure 4.2**). This leads to greater savings than a simple difference between the cases, while still having smaller savings than would be derived by comparing a fuel cell vehicles case with the Baseline Case. **Table 4.11** presents the overall benefits.

Table 4.11. FY06 Benefits Estimates for Hydrogen, Fuel Cells, and Infrastructure Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	ns	ns	ns	0.16
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	ns	ns	2.4
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.0	0.0	0.0	4.6
Security				
Oil Savings (million barrels per day)	ns	0.01	0.04	0.23
Natural Gas Savings (quadrillion Btu/yr)	ns	ns	-0.01	-0.30
Avoided Additions to Central Conventional Power (gigawatts)	ns	1	ns	2
Program-Specific Electric Capacity Additions (cumulative gigawatts)	ns	1	ns	ns

Industrial Technologies Program

The Industrial Technologies Program covers primarily the energy-intensive basic materials processing industries, as well as some key technologies that are common across most industries, with the objective of increasing energy efficiency. These can be characterized in two categories, R&D and deployment. The R&D projects generally apply to specific industries or to specific technologies that cut across industries. The R&D projects seek to develop new or improved technologies that are more energy efficient and more cost-effective than the alternatives currently available. The deployment projects seek to increase the adoption of existing, as well as new, energy-efficient technologies.

The heterogeneity of the program makes it difficult to represent the program activities explicitly through technologies in the NEMS-GPRA06 framework. Therefore, analysts perform an off-line analysis using detailed spreadsheet models, and use the resulting energy savings by fuel type to provide inputs into the integrated model. Because these programs cannot be modeled on an economic basis, analysts reduce the off-line energy savings by an "integration factor" before putting them into NEMS-GPRA06. This is to account for interactions among programs and feedback effects that could not be considered in their original estimation. The amount of the integration factor is based on how much program overlap or "integration" was captured by the off-line tools and is based on the expert judgment of the benefits analysis team. The crosscutting programs, including the Best Practices activity, were reduced by 10 percent. The Industries of the Future programs were not reduced because they are relatively specific and not likely to experience overlap with other industrial programs.

Analysts then run the fully integrated NEMS-GPRA06 to compute the benefits metrics of primary energy savings, carbon emission reductions, and energy-expenditure savings that are associated with the fuel-consumption reductions.

The resulting estimated primary savings are slightly lower than those targeted because of feedback effects that come through the integration with other sectors. The primary feedback effect occurs through lower fuel prices. In this case, the lower energy consumption causes lower energy prices (although the feedback is small), which causes energy consumption to be higher than it otherwise would have been, leading to slightly lower program savings (**Table 4.12**).

Table 4.12. FY06 Benefits Estimates for Industrial Technologies Program (NEMS-GPRA06)

Benefits	**2010**	**2015**	**2020**	**2025**
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.25	0.80	1.77	2.16
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	2.2	11.2	16.9	12.9
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	4.7	14.8	34.7	44.4
Security				
Oil Savings (million barrels per day)	0.03	0.14	0.19	0.15
Natural Gas Savings (quadrillion Btu/yr)	0.12	0.30	0.64	0.72
Avoided Additions to Central Conventional Power (gigawatts)	ns	2	9	8
Total Electric Capacity Avoided (cumulative gigawatts)	1	3	8	11

Solar Energy Technologies Program

The Solar Energy Technologies Program develops both thermal-heat and electric-solar technologies. The solar water-heating component is focused on developing low-cost solar hot water and pool heaters to displace fossil-fueled or electric alternatives. Photovoltaics (PVs) are being improved for both distributed and central electricity generation applications, and the program is working to accelerate PV adoption through the Million Solar Roofs Initiative. The Concentrated Solar Power R&D activity is developing better technology for large-scale central electricity generation facilities that concentrates solar energy to produce electricity through a thermal process.

The benefits for solar water heat are represented within the residential module of NEMS-GPRA06. The solar water heater is a specific technology defined by its capital cost, O&M costs, and electrical use. NEMS-GPRA06 was modified to add solar water heat as an option for new homes, and the algorithm governing water-heater replacements was modified so that solar water heaters could compete in a larger market. In the Program Case, the baseline assumptions were modified to reflect the program cost and performance goals. The costs were changed for both new and replacement water heaters.

Three changes were made to the representation of distributed PV systems in the Baseline and Program Cases. The size of the typical distributed PV installation was increased to 4 kW per home (from 2 kW) and to 100 kW per commercial building (from 25 kW) to reflect literature on recent installations. In addition, the fraction of eligible buildings was increased from 30 percent to 60 percent for homes and to 55 percent for commercial buildings. The California renewable energy credit program, which provides a PV credit of $4000/kW in 2003 declining by $400/kW per year, was included for the Pacific region. For the program case, the capital and O&M costs were modified to reflect the program's goals. The regional capacity factors in the Baseline Case were similar to those in the program's goals, so they were left unchanged.

The improved concentrated solar power (CSP) technology was represented by declining capital costs over time and higher capacity factors. The capital costs goals are higher than those used in the Baseline but represent systems with significantly more storage and therefore higher electrical output. A set of capacity factors by time periods within a year were computed by analysts to optimize the timing of solar output for each region within the bounds of the storage potential. The capacity factors and capital costs vary by region due to difference in solar insolation and resulting storage costs.

In addition to competing on an economic basis with other electricity-generation technologies, PVs may be constructed for their environmental benefits. PERI, using their Green Power Market Model, provided an estimate of PV capacity additions in response to the expanding green power markets in many places throughout the country. The projections for green power PV installations were combined with the Million Solar Roofs Initiative goals to determine the planned PV capacity additions that were incorporated into NEMS-GPRA06. **Table 4.13** shows the baseline, program case, and incremental capacity and electricity generation for the solar technologies.

Table 4.13. NEMS-GPRA06 Solar Capacity (GW) and Water Heaters

Solar Generation Technologies	**2010**	**2015**	**2020**	**2025**
GPRA Base				
Solar CSP	0.4	0.5	0.5	0.5
Central PV	0.2	0.2	0.3	0.4
Distributed PV	0.4	0.4	0.4	3.8
Total	1.0	1.1	1.2	4.7
Solar Program Case				
Solar CSP	0.4	0.5	0.5	2.2
Central PV	0.2	0.2	0.3	0.4
Distributed PV	1.2	3.0	6.5	15.2
Total	1.8	3.7	7.4	17.8
Incremental Capacity				
Solar CSP	0.0	0.0	0.0	1.7
Central PV	0.0	0.0	0.0	0.0
Distributed PV	0.8	2.6	6.2	11.4
Total	0.8	2.6	6.2	13.1

Incremental Generation (BkWh)				
Solar CSP	0.0	0.0	0.0	10.8
Central PV	0.0	0.0	0.0	0.0
Distributed PV	1.7	5.2	12.6	23.6
Total	1.7	5.2	12.6	34.4

Solar Water Heaters

	2010	**2015**	**2020**	**2025**
GPRA Base				
Million	0.61	0.81	1.04	1.40
Share (percent)	0.5%	0.6%	0.8%	1.0%
Solar Program Case				
Million	0.92	2.33	3.81	5.73
Share (percent)	0.8%	1.9%	2.9%	4.2%

Estimates of primary energy, oil, and carbon emissions savings result from displacement of energy use for water and pool heating, and from electricity demand reductions and PV and CSP generation. The savings associated with reduced conventional electricity requirements depend on which types of generating plants were built and operated in the Baseline Case. Over time, the mix of fuels and efficiencies of power generation vary; and, therefore, the energy savings will as well. Energy-expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers. Energy savings from water heaters also directly reduce energy expenditures. Overall benefits of the Solar Energy Technologies Program are shown in **Table 4.14**.

Table 4.14. FY06 Benefits Estimates for Solar Energy Technologies Program (NEMS-GPRA06)

Benefits	**2010**	**2015**	**2020**	**2025**
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.01	0.05	0.12	0.30
Generation (gigawatt-hours/yr)	2	5	13	34
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	1.1	2.7	1.8
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.1	1.0	2.4	7.6
Security				
Oil Savings (million barrels per day)	ns	0.01	0.01	ns
Natural Gas Savings (quadrillion Btu/yr)	0.01	0.03	0.03	0.01
Avoided Additions to Central Conventional Power (gigawatts)	ns	2	4	9
Program-Specific Electric Capacity Additions (cumulative gigawatts)	1	3	6	13

Vehicle Technologies Program

The Vehicle Technologies Program consists of research on light-duty vehicle hybrid and diesel technologies, heavy vehicle engine/drivetrain and parasitic loss-reduction technologies, and lightweight materials for engines and vehicles. In addition, the program includes research in advanced petroleum and renewable fuels, the benefits of which are not modeled.

Light-duty vehicle hybrid and diesel technologies: This research aims to improve engine technologies in light-duty vehicles, which include passenger cars and light-duty trucks. NEMS-GPRA06 is used to compute benefits estimates for these activities through a process that estimates the penetration (sales) of the various technologies in the market for light-duty vehicles over time. The amount that each technology penetrates into the market determines the stock of these vehicles and the vehicle miles traveled (VMT) associated with each technology.

Heavy vehicle engine/drivetrain and parasitic loss reduction technologies: Heavy vehicles are those that have a gross weight (the weight when fully loaded) of 10,000 pounds or more. This program researches multiple technologies including engines/drivetrains, parasitics/accessories, aerodynamics, and hybrids. The benefits of this R&D activity are derived from penetration rates estimated by the Heavy Truck Energy Balance and Truck 2.0 models developed for the Vehicle Technologies Program, using efficiency and technology cost assumptions.

Lightweight materials for engines and vehicles: The lightweight materials developed under this R&D activity are used in both light and heavy vehicles. The effect of these materials are included in the projection of vehicle attributes and not modeled separately.

In the NEMS-GPRA06 integrating model, the light-duty vehicle (LDV) market consists of six car classes—mini-compact, subcompact, compact, midsize, large, two-seater—and six light-duty truck classes—small and large pickup, small and large van, small and large sport utility vehicle (SUV)—in nine Census divisions. For each vehicle type and class and for each region, a number of LDV technologies compete against each other in the market for vehicle sales. These include conventional gasoline, advanced combustion diesel, gasoline hybrids, diesel hybrids, gasoline fuel cell, hydrogen fuel cell, electric, natural gas, and alcohol. Each vehicle technology is represented by a number of characteristics that can change over the forecast time horizon and that influence the technology's acceptance in the marketplace (*i.e.*, its sales). These characteristics include the vehicle cost, the fuel cost per mile (a combination of the fuel price and the vehicle efficiency), the vehicle range, the operating and maintenance cost, the acceleration, the luggage space, the fuel availability, and the make and model availability. The NEMS-GPRA06 model also includes "calibration" coefficients to calibrate the model to historical data. The associated characteristics for all the alternative technologies are specified as relative to those for the conventional gasoline vehicle.

The model estimates the sales-penetration share of each technology in all of the vehicles, classes, and regions in each year of the forecast. The various characteristics of the technologies determine the technology's value to consumers and its acceptance in the marketplace, but each characteristic has a differing degree of influence.[7] The vehicle cost is generally the most

[7] The vehicle shares are sensitive to assumptions about consumer preference for each vehicle attribute. In the NEMS-GPRA06 transportation model, a different set of consumer-choice assumptions is made than those in the NEMS *AEO2004* transportation model, leading to different rates of technology adoption.

influential of the characteristics, certainly having a much stronger influence than luggage space, for example. The values of all the characteristics are combined to create an overall value. The technologies are competed against each other using a nested logit formulation. In a logit formulation, the relative size of the overall value for each technology determines the relative penetration shares for that technology. Technologies that have higher values are given greater sales shares, resulting in a distribution of consumer preferences rather than the technology with the highest "utility" receiving 100 percent of the market. The overall sales-penetration results are the sum of all the more disaggregated results.

In the FY 2006 benefits analysis, the Baseline Case for transportation programs is essentially the *AEO2004* Reference Case, which already includes some small amount of penetration for the program vehicle technologies. The Program Case uses the program technology characteristics, along with a variety of other assumptions relating to behavioral responses in the underlying logit formulation of the NEMS-GPRA06 model. These include moving away from the "calibration" coefficients over the forecast period (used by the model for a tie to history), and reworking the manner in which the make and model availability coefficients are used.

Using the fully integrated NEMS-GPRA06 model, the overall sales share for gasoline vehicles in 2025 falls from 81 percent in the Baseline Case to 40 percent in the Program Case (**Figure 4.3**). This decrease in share is due to the penetration of the alternative technologies. The overall share in 2025 for advanced combustion diesel increases from 5 percent to 25 percent, for gasoline hybrids from 5 percent to 18 percent, and for diesel hybrids from 1 percent to 12 percent.

These large vehicle sales shares for advanced technology vehicles in 2025, however, translate into much smaller shares of overall vehicle stocks and overall shares of vehicle miles traveled (VMT) for each technology. The stock shares depend on the share of sales over time, which only gradually increases for the alternative-technology vehicles, and the rate of vehicle replacement and growth. The total VMT for gasoline vehicles falls from 3,455 billion miles in 2025 to 2,667 (just over 60 percent of the VMT) between the two cases (**Figure 4.4**). The total VMT for advanced combustion diesel increases from 180 to 519 billion miles (12 percent), for diesel hybrids from 20 to 218 billion miles (5 percent), and for gasoline hybrids from 182 to 710 billion miles (16 percent).

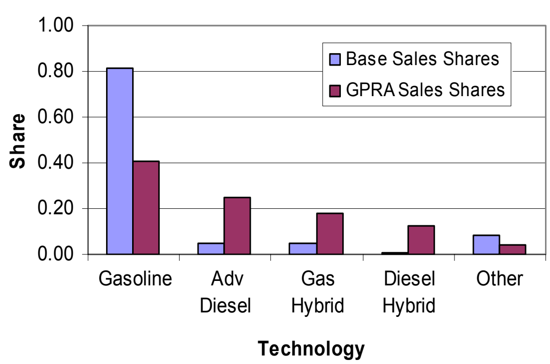

Figure 4.3. Sales Shares in 2025

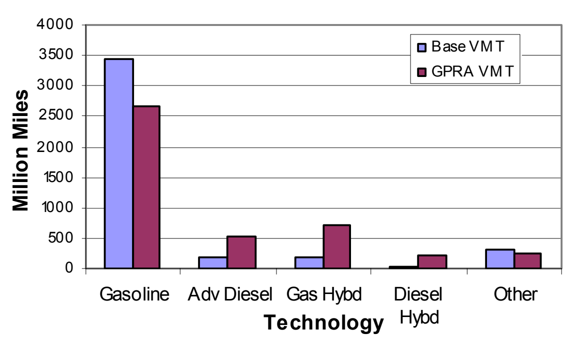

Figure 4.4. Vehicle Miles Traveled in 2025

The miles per gallon (MPG) for advanced combustion diesel and for hybrid vehicles is much greater than the MPG for conventional gasoline vehicles. As a consequence, since these advanced-technology vehicles are substituting for the conventional gasoline vehicles, there is a considerable amount of fuel savings.

In these fully integrated NEMS-GPRA06 model runs, the savings are typically somewhat less than if they were estimated in a transportation-only model, because of feedback effects that come through the integration with other sectors. The primary feedback effect occurs through lower fuel prices. In this case, reduced gasoline demand causes lower gasoline prices, which leads to an increase in travel and less-efficient vehicle purchases than would otherwise have occurred absent the price change. The rebound of gasoline consumption reduces the program savings. At the same time, energy-expenditure savings are greater. The small decreases in price apply to the total amount of fuel consumed and contribute significant additional expenditure savings. In addition, the "rebound" effect is also influenced by the fact that vehicles are more efficient, thereby reducing the cost to drive, causing more miles to be driven. **Table 4.15** presents the total program benefits, including those of heavy trucks.

Table 4.15. FY06 Benefits Estimates for Vehicle Technologies Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.09	0.73	2.12	3.98
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	ns	7.3	31.4	60.9
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	1.9	14.6	41.8	76.2
Security				
Oil Savings (million barrels per day)	0.04	0.32	0.90	1.80
Natural Gas Savings (quadrillion Btu/yr)	ns	ns	ns	ns
Avoided Additions to Central Conventional Power (cumulative gigawatts)	ns	ns	ns	ns

Weatherization and Intergovernmental Program

The Weatherization and Intergovernmental Program (WIP) encompasses a broad range of activities in virtually all demand sectors of the energy economy. These activities generally are comprised of market enhancement, rather than R&D. The major components include: International, Native American Renewable Initiative (also referred to as Tribal Energy), the Renewable Energy Production Incentive (REPI), Weatherization (Assistance), State Energy Program Grants, and Gateway Deployment (Energy Star, Clean Cities, Inventions and Innovations, Rebuild America, Energy Efficiency Information and Outreach, and Building Codes Training and Assistance). The FY 2006 benefits estimate methodologies vary by activity.

The international activities are currently outside the scope of the integrated modeling framework. The Native American renewable initiative also is not being modeled for this year. REPI provides payments to publicly owned utilities, such as municipal utilities or rural electric cooperatives, for electricity generation from renewable energy sources that is the public power equivalent of the production tax credit for investor-owned renewable generators. Analysts projected the amount of new renewable generation that is likely to be stimulated by future REPI payments. Almost all the new generation is expected to be wind, based on the eligibility criteria and past experience. Analysts then used the NEMS-GPRA06 benefits for the Wind Program to develop the benefits metrics for REPI based on the ratio of additional generation.

Weatherization and State Energy Program grants are implementation programs that lead to greater adoption of energy efficiency. They are represented in NEMS-GPRA06 by reducing energy consumption in the residential and commercial sectors, based on the program goals.

The Clean Cities subprogram is represented through an increase in alternative-fuel vehicles and an increase in dedicated ethanol (E85) vehicles and fuel usage. For the increase in alternative-fuel vehicles, analysts determined the cumulative number of expected vehicles participating in Clean Cities through off-line analysis. These were converted to annual vehicle sales and used as inputs into NEMS-GPRA06. The incremental sales were allocated to vehicle types, based on program information, although the fuel types in the model do not directly correspond in all cases. The largest share of vehicles are compressed natural gas, ethanol, and liquefied petroleum gas. Electric and methanol vehicle shares are small. For the portion of the program that encourages greater ethanol use, analysts determined the change in the fraction of vehicles using E85 over time and an increasing fraction of E85 use per vehicle. These were converted to overall fractions of E85 use and were then used as inputs to NEMS-GPRA06.

The Inventions and Innovation (I&I) subprogram savings estimates are based on numerous individual technologies receiving grants in the previous year, because this is the most recent year of award data available for analysis. For this analysis, the projects with the greatest expected energy savings are represented using specific technology characteristics or by targeting the energy-savings goals of the individual projects funded. The technologies include two inventions involving ethanol production, two types of buildings equipment, and one industrial process. The ethanol and industrial process inventions could not be modeled on an economic basis within NEMS-GPRA06, so the estimated off-line energy savings were used in the model after being discounted by 30 percent to 50 percent to reflect potential interactions with other EERE markets and technologies. In the building sector, the electrochromic windows reduce heating and cooling loads. Based on an analysis performed by PNNL,[8] the windows were modeled in NEMS-GPRA06 based on technology cost and efficiency characteristics. The humidity-control invention was modeled using an assumption of air-conditioning savings in homes with commercial applications and in the markets where humidity control is important.

Analysts represented the Energy Star activities of Gateway Deployment by modifying the consumer-behavior coefficients, indicating how consumers trade first-cost expenditures for annual energy savings. The program goals for market penetration were used to determine the degree of change of these parameters. For the compact fluorescent bulb (CFL) activities, the target market share was defined as the fraction of lighting demand rather than the fraction of bulbs, in order to reflect that CFLs are most likely to be installed in high-use fixtures.

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[8] See Appendix K on the Weatherization and Intergovernmental Program analysis.

Other buildings energy-related activities, including Building Codes and Rebuild America, were represented in NEMS-GPRA06 based on an offline analysis of penetration rates and efficiency improvements. Overall benefits for WIP are shown in **Table 4.16**.

Table 4.16. FY06 Benefits Estimates for Weatherization and Intergovernmental Program (NEMS-GPRA06)

Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Nonrenewable Energy Savings (quadrillion Btu/yr)	0.34	0.61	0.97	1.22
Economic				
Energy-Expenditure Savings (billion 2002 dollars/yr)	4.6	10.4	11.9	9.6
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	6.3	12.3	21.0	27.2
Security				
Oil Savings (million barrels per day)	0.03	0.08	0.08	0.05
Natural Gas Savings (quadrillion Btu/yr)	0.20	0.20	0.26	0.31
Avoided Additions to Central Conventional Power (gigawatts)	1	9	16	15
Total Electric Capacity Avoided (cumulative gigawatts)	7	11	12	14

Wind Technologies Program

The wind component of the Wind Technologies Program seeks to reduce the cost—and improve the performance—of wind generation. The FY 2006 benefits are based primarily on projecting the market share for wind technologies, based on their economic characteristics.

Representation of Wind: The NEMS-GPRA06 electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (*i.e.*, availability), the regional load requirements, and existing capacity resources. Unlike the *AEO2004* version of NEMS, NEMS-GPRA06 characterizes wind by three wind classes, which each have their own capital costs and resource cost multipliers. For example, wind turbines being developed by the program for use in Class 4 winds are expected to be more expensive, but deliver more electricity per unit of capacity. The regional resource cost multipliers act to increase costs as more of a wind class is developed in a region, and development may move to the next most cost-effective wind class. The same resource multipliers are used as in the *AEO2004*, although they are applied at the class level rather than for the entire regional resource. NEMS-GPRA06, as in the *AEO2004*, assumes that the capacity value of wind diminishes with greater wind capacity in a region. Finally, another constraint on the growth of wind-resource development is how quickly the wind industry can expand before costs increase due to manufacturing bottlenecks. The *AEO2004* assumption that a cost premium is imposed when new orders in a year are 20 percent higher than in the highest of the previous 10 years was maintained in the Program Case[9] (see **Table 4.17**).

[9] In the *AEO2004,* all generation technologies face similar premiums associated with rapid growth.

The baseline characterization of wind capital costs and capacity factors were modified to reflect a more consistent view relative to the program goals. The Baseline costs were raised slightly and distinguished between Class 5 and 6 versus Class 4 costs. The more significant change was an increase in capacity factors for all three wind classes. This reduced the benefits attributed to the program, but presents a better representation of the impact of the program's R&D.

NEMS-GPRA06 also includes a representation of offshore wind that it not in the AEO2004 version. The offshore wind is represented as a distinct technology that competes with all other generation technologies. It is characterized in a similar manner as onshore wind, with three wind classes, but also has a distinction between shallow and deep-water sites. The constraints on intermittent generation and rapid growth apply similarly to offshore as to onshore wind development. The offshore wind does not have the regional resource cost multipliers because there is insufficient data on how they might apply.

Analysts represented the Wind Program R&D activities by reducing the capital and O&M costs and increasing the performance of wind capacity to match the program cost goals. In addition to competing on an economic basis with other electricity-generation technologies, wind capacity may be constructed for its environmental benefit. PERI, using their Green Power Market Model, provided an estimate of wind capacity additions in response to the expanding green power markets in many places nationwide. Analysts incorporated the projections for green power wind installations into NEMS-GPRA06 as planned capacity additions. These are quite small relative to the economic additions selected within the model.

Table 4.18 provides the estimates of primary energy, oil, and carbon emissions savings stemming from wind and hydropower displacing fossil-fueled generation sources. Analysts measure the energy-expenditure savings as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers.

Table 4.17. Wind Capacity (GW)

		2010	2015	2020	2025
AEO Base		7.9	9.5	12.0	14.0
GPRA Baseline					
Onshore	Class 6	6.1	6.5	6.5	6.5
	Class 5	4.9	6.2	6.7	7.4
	Class 4	0.1	0.1	0.1	0.2
	Subtotal	11.1	12.8	13.3	14.2
Offshore	Class 7	0.0	0.4	1.2	1.4
	Class 6	0.0	0.0	0.0	0.0
	Class 4&5	0.0	0.0	0.0	0.0
	Subtotal	0.0	0.4	1.2	1.4
Total	Total	11.1	13.2	14.5	15.6
Wind Program Case					
Onshore	Class 6	6.1	10.8	11.3	11.3
	Class 5	7.8	16.5	18.7	20.7
	Class 4	0.1	14.4	36.3	37.6
	Subtotal	13.9	41.7	66.4	69.6
Offshore	Class 7	0.0	1.9	16.7	37.2
	Class 6	0.0	0.0	1.7	2.1
	Class 4&5	0.0	0.0	0.0	0.0
	Subtotal	0.0	1.9	18.4	39.2
Total	Total	13.9	43.6	84.8	108.8
Incremental Capacity					
Onshore	Class 6	0.0	4.3	4.8	4.8
	Class 5	2.8	10.3	12.1	13.2
	Class 4	0.0	14.2	36.2	37.4
	Subtotal	2.8	28.8	53.0	55.4
Offshore	Class 7	0.0	1.5	15.5	35.8
	Class 6	0.0	0.0	1.6	2.0
	Class 4&5	0.0	0.0	0.0	0.0
	Subtotal	0.0	1.5	17.2	37.8
Total	Total	2.8	30.3	70.2	93.2

Table 4.18. FY06 Benefits Estimates for Wind Technologies Program (NEMS-GPRA06)

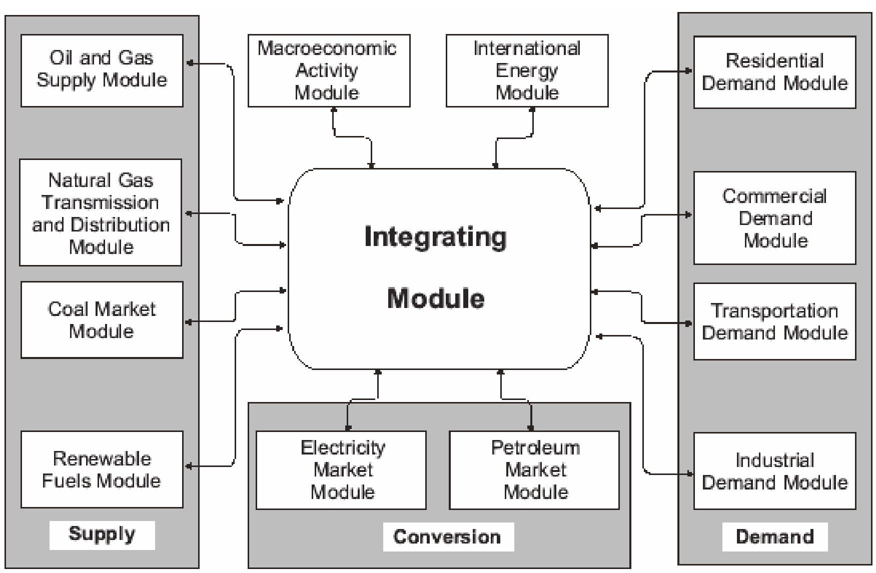
Benefits	2010	2015	2020	2025
Energy Displaced				
Primary Non-Renewable Energy Savings (quadrillion Btu/year)	0.04	0.84	2.29	3.32
Generation (gigawatt-hours/year)	11	120	298	416
Economic				
Energy Expenditure Savings (billion 2000 dollars/year)	ns	5.2	6.8	4.5
Environmental				
Carbon Savings (million metric tons carbon equivalent/year)	0.9	18.0	52.4	80.6
Security				
Oil Savings (million barrels per day)	ns	0.06	0.07	0.06
Natural Gas Savings (quadrillion Btu/year)	0.01	0.24	0.52	0.39
Avoided Additions to Central Conventional Power (gigawatts)	1	9	19	24
Program-Specific Electric Capacity (cumulative gigawatts)	3	30	70	93

Box 4.1—EIA's National Energy Modeling System (NEMS)*

The National Energy Modeling System (NEMS) is an energy-economy modeling system of U.S. energy markets for the midterm period through 2025. NEMS projects the production, imports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics. NEMS was designed and implemented by the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE). As described in the GPRA Baseline section, the NEMS-GPRA06 version of the model used for the EERE GPRA analysis includes minor modifications to the standard EIA NEMS.

NEMS is designed as a modular system. Four end-use demand modules represent fuel consumption in the residential, commercial, transportation, and industrial sectors; subject to delivered fuel prices, macroeconomic influences, and technology characteristics. The primary fuel supply and conversion modules compute the levels of domestic production, imports, transportation costs, and fuel prices that are needed to meet domestic and export demands for energy; subject to resource base characteristics, industry infrastructure and technology, and world market conditions. The modules interact to solve for the economic supply and demand balance for each fuel. Because of the modular design, each sector can be represented with the methodology and the level of detail (including regional detail) that is appropriate for that sector.

A key feature of NEMS is the representation of technology and technology improvement over time. Five of the sectors—residential, commercial, transportation, electricity generation, and refining—include extensive treatment of individual technologies and their characteristics, such as the initial capital cost, operating cost, date of availability, efficiency, and other characteristics specific to the sector. Technological progress results in a gradual reduction in cost and is modeled as a function of time in these end-use sectors. In addition, the electricity sector accounts for technological optimism in the capital costs of first-of-a-kind generating technologies and for a decline in cost as experience with the technologies is gained both domestically and internationally. In each of these sectors, equipment choices are made for individual technologies as new equipment is needed to meet growing demand for energy services or to replace retired equipment. In the other sectors—industrial, oil and gas supply, and coal supply—the treatment of technologies is more limited, due to a lack of data on individual technologies. In the industrial sector, only the combined heat and power and motor technologies are explicitly considered and characterized. Cost reductions resulting from technological progress in combined heat and power technologies are represented as a function of time as experience with the technologies grows. Technological progress is not explicitly modeled for the industrial motor technologies. Other technologies in the energy-intensive industries are represented by technology bundles, with technology possibility curves representing efficiency improvement over time. In the oil and gas supply sector, technological progress is represented by econometrically estimated improvements in finding rates, success rates, and costs. Productivity improvements over time represent technological progress in coal production.



* Most of this description is taken from *The National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March 2003.